

Training Metacognitive Skills for Situation Assessment

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Abstract

A model of situation assessment is proposed that integrates processes of recognition and metacognition. The model consists of memory structures that represent what is believed, value/action structures that represent the values placed on those beliefs, and metacognitive processes used to test, critique, and correct situation comprehension. Training implications are derived from the model, and an ongoing study of metacognitive skills training is described.

1. Introduction

The evolution of Army doctrine and practice towards flexible and independent planning poses a significant challenge to existing thinking about battlefield situation assessment. One example of this trend is the concept of battlespace, which is a spatial and temporal mental model composed by the individual officer, that encompasses his command's capabilities and interests. A second example is the new emphasis on using abbreviated methods of planning in time-stressed situations. These methods focus on a single best course of action and abandon the exhaustive analytical models previously endorsed for situations where time is scarce. This shift to flexible methods and independence of command places a significant new burden on officers. It requires that they have skills in situation assessment and planning that previously were attributed to their senior command.

At the same time that Army doctrine is changing to increase emphasis on situation assessment skills, recent cognitive research promise to leverage our understanding of situation assessment and planning, and help us to devise better training and decision aids.

The research to which we refer concerns the role of recognition and metacognition in expert performance. It is the foundation for an alternative to analytical and recognitional models of decision making. We call this the adaptive model of decision making (Cohen, 1993a).

According to the analytical or normative approach, an assessment is rational if it is founded on a logically consistent set of judgments about probabilities and values. Consistency is defined with respect to formal constraints dictated by "self-evident" axioms. There is ample research claiming that unaided human decisions do not satisfy such constraints. Indeed, systematic errors, or "biases," have been identified at virtually every stage of the decision making process (Cohen, 1993b; Kahneman, Slovic, and Tversky, 1982). Analytical methods do not reflect the way actual expert decision makers handle problems, particularly in complex situations requiring rapid situation assessment and planning.

The recognitional viewpoint equates successful assessment with a virtually automatic (rather than controlled) response to environmental patterns, sensitive detection of stimuli near the threshold of awareness, and the use of easily retrieved, task-specific encodings in skilled memory. A view of this kind has also appears in research on expert-novice differences in a variety of domains. Beginning with Chase and Simon's (1973) work on chess, expertise has been equated with mastery of a large repertoire of familiar patterns and their associated responses. However, pattern-recognition views say little about decision making in novel problems. How are schemas updated and maintained in new and changing circumstances? How are conflicting and unreliable data dealt with? How do decision makers change their minds? It is clear that simple pattern-matching and retrieval are not the whole story.

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In this paper, we explore a third approach to modeling and training battlefield situation assessment. It is a naturalistic approach in which analysis of decision evaluation begins with the way experienced, effective decision makers actually make decisions in real-world tasks (Klein, Orisanu, Calderwood, & Zsombok, 1993, Holyoak, 1993). To this end we have interviewed 33 Lt. Colonels and Majors responsible for planning at the division, brigade, and battalion levels concerning their experiences in assessing battlefield situations. We have found, as have others in expert-novice research, that these officers use methods that combine pattern recognition with strategies for effectively facilitating recognition, verifying its results, and constructing adequate models when recognition fails. From this foundation, we have developed an

“adaptive model” of decision making that integrates recognition and metacognitive processes.

2. The Model

2.1 Overview

The framework that we propose for analyzing battlefield situation assessment framework consists, at the most general level, of four components (see figure #1):

1. The real-world environment.
2. Memory and knowledge structures;
3. Actions, goals, and values; and
4. Processes for regulating and monitoring cognition

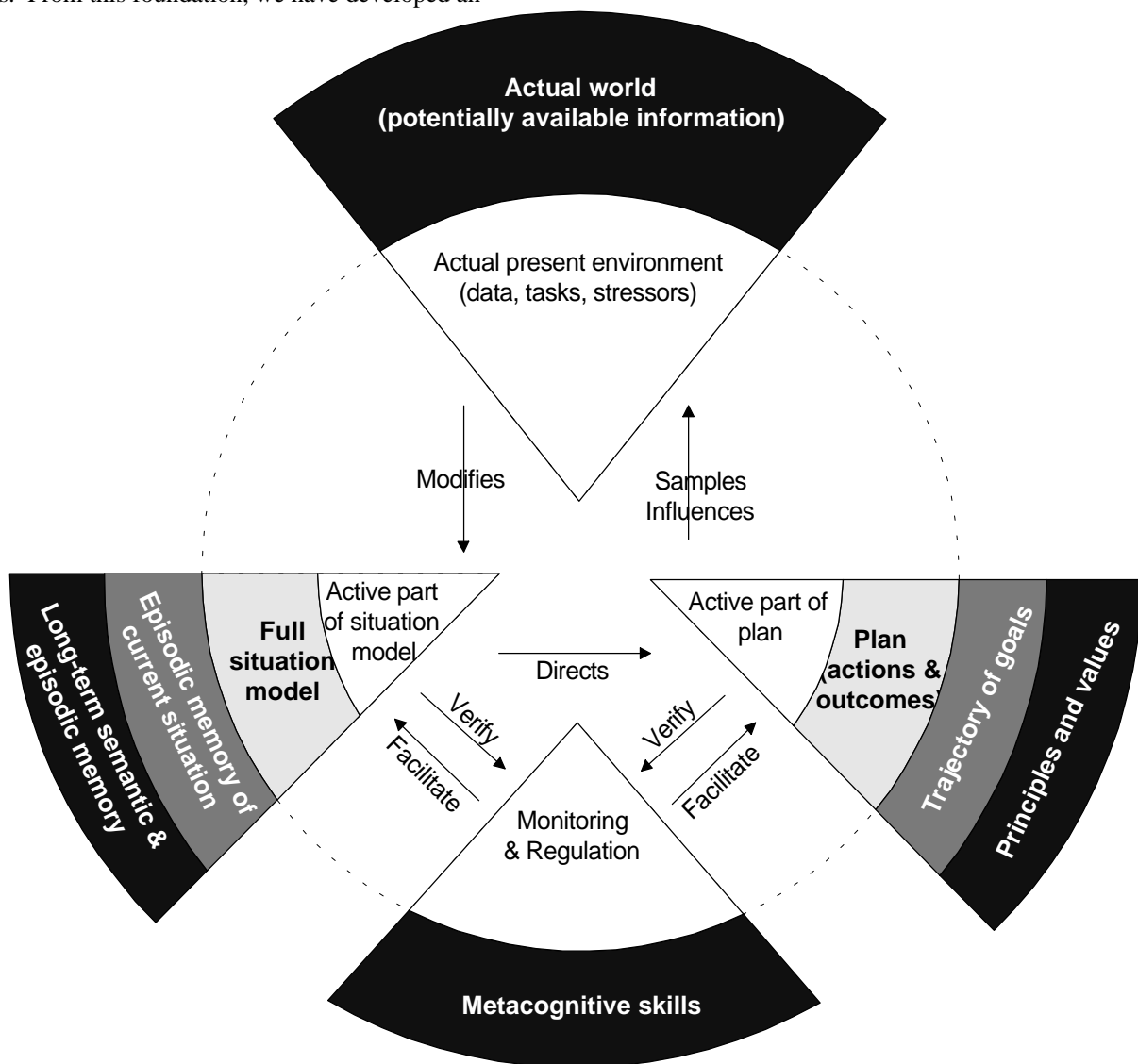


Figure 1: Framework for the adaptive decision-making model.

The figure represents these components as arcs that comprise a circle. The diagram partitions these components with concentric circles, which represent different aspects of memory, from the immediate focus of working memory in the innermost ring, to the contents of long-term semantic and episodic memory in the outer ring (as discussed in the following section).

The basic form of the framework is inspired by Neisser (1976). In his concept of the perceptual cycle, knowledge structures called schemas actively direct actions such as attending to and exploring the environment. The real-world information generated by that exploration then causes changes in the schemas. These interactions cycle continuously as the observer gains understanding of the actual world. Connolly and Wagner (1988) extended Neisser's concept to include decision cycles, in which exploration of the environment causes decision makers to refine their goals. We have incorporated this extension, and have added the iterative role of metacognition, i.e., monitoring and regulating one's own cognitive processes, in learning both about the world and about one's own goals.

The operation of this expanded model is more complex than that of Neisser's original. Neisser's perceptual cycle comprised only the sequence from knowledge to action to real-world and back to knowledge. Our notion of cognitive cycle, however, includes many other, more complex possibilities. The metacognitive component critiques and corrects situation knowledge and plan knowledge; plan knowledge directs sampling of the environment; these perceptual samples modify situation knowledge, which can direct the composition of plan knowledge without the mediation of metacognitive processes. As just one example of the potential cycles of assessment, an initial knowledge structure may be checked by metacognitive processes, modified, and checked again, before leading to an action plan, which is also checked by metacognition before being implemented in the environment, resulting in new knowledge.

To understand the potential of the model, it is important to examine each of its three cognitive components (excluding the environment) more closely.

2.2 Situation knowledge: Enemy plan structures & Action schemas

We partition knowledge structure in this model, as do Adams, Tenney, and Pew (1991), into four segments:

1. The explicit focus of working memory (representing the currently attended part of the situation),
2. The implicit focus of memory (containing the full situation model),

3. Current episodic memory (containing the history of the current problem), and
4. Long-term memory (with both semantic and episodic contents).

Long-term knowledge takes the form of memory schemas. These are used to organize situation assessment information. More proficient situation assessors appear to use a variety of schemas. Among the most common are the *enemy plan schema* and the *action schema*.

Commanders use enemy plan structures organize information about enemy interests, strengths, and location, and describe how they lead to intentions, actions, and consequences. Take, for example, a situation in which a U.S. officer must infer the intent and actions of an enemy who may attack along northern or southern fronts. The officer knows that tanks are a prime source of enemy strength, and that U.S. forces have situated tank killing systems in a southern region. Enemy interests (a term we use broadly define to include values, doctrine, and goals) include doctrine to avoid opposing strength, such as northern U.S. tank killing systems. Finally, enemy location allows attack in the north or south because terrain is hospitable in both areas. These factors enable the U.S. officer to infer that the enemy intent is to attack to the north, that this will involve such actions as moving artillery, massing troops, and command facilities to the north. These enemy's intended consequence will be a northern breakthrough.

The action schema builds on the enemy plan structure. It describes three modes of inferring enemy intent: proactive, predictive, reactive.

In the proactive mode, the officer's conception of the situation is predicated on molding enemy intent by shaping the battlefield, and specifically by altering the enemy's perception of his own interests, strength or location. For example, an officer's assessment of a situation may assume that his planned deceptions will influence enemy estimations of relative strength, and that the deceptions will persuade the enemy to adopt an intent to attack a force that is, in fact, superior to his own.

The predictive orientation is one in which the commander uses his knowledge of enemy interests, strength and location to predict enemy intent. For example, the officer who understands the enemy interest, strength and location described above might predict the northern attack.

In the reactive mode, a commander infers enemy intent from the actions the enemy carries out, or by observing their consequences. The commander hit from the north by enemy tanks would, clearly, infer the enemy's intent, and possibly reconstruct the causal chain to that intent from enemy interests, strength and location.

These strategies are not mutually exclusive. A predictive strategy may employ reactive methods (i.e., observations of enemy actions) to confirm the predictions. A proactive strategy may use predictive methods to decide what actions would produce the desired enemy intent, and may use reactive methods to confirm that the attempt to influence enemy intent was successful.

There are a range of other schemas that officers bring to bear on situation assessment. We will not discuss them here, but the following list conveys their character:

- Enemy goal structures describe the hierarchical and compensatory relationships among ultimate values, principles, goals, and actions.
- Temporal plan execution structures provide a more detailed description of the temporal durations, precedence relations, and causal contingencies among actions and events.
- Enemy planning/C2 structures describe the enemy roles and activities involved in producing, communicating, and implementing plans.
- Terrain structures relate terrain features to expected enemy actions and prescribed friendly actions.

2.3 Plan/Goal knowledge: Value/action structures

Actions, goals, and values reflect a qualitatively different way of viewing knowledge. They represent how possible states of affairs are valued, whereas situation knowledge represents how strongly they are believed. Values or preferences are importantly different from strengths of belief. They influence beliefs, but are separate from them. We draw on Beach's (1993) concepts of the value image, trajectory image, and strategic image to define these segments.

High-level values and principles are relatively permanent knowledge about what the decision maker regards as desirable, important, and worth pursuing.

Current goals are episodic memory structures. Goals are sequences of desired states; they are concrete realizations of high-level values and principles in the current situation. They give meaning to specific plans, and are used to generate plans.

The current plan is the detailed set of actions and action contingencies that the decision maker has adopted in the current situation. It includes the specific actions (e.g., "move up follow-up forces," "emplace artillery," look for a kill zone, etc.) undertaken to realize goals.

The part of the plan active in working memory is the immediate focus of evaluation. Such evaluation may occur prior to implementation as part of the decision making process, or during implementation by monitoring an on-going action for its success in achieving goals.

Processing of actions, goals and values can be either top down or bottom up (Beach, 1990). Actions and plans may be generated and evaluated based on goals, and modified or rejected if they fail to achieve them. Similarly, goals may be generated and evaluated based on values. On the other hand, from a bottom-up perspective, goals may be revised if no actions can be found to achieve them. Even high-level values (such as avoiding one's first defeat) might be revised (perhaps rationalized away) if they are not achievable by realistic goals or actions.

2.4 Metacognitive knowledge: Overview

Metacognition consists of functions that monitor and regulate thought. It has been defined as "individuals' knowledge of the states and processes of their own mind and/or their ability to control or modify these states and processes" (Gavelek and Raphael, 1985).

Metacognition is the focus of considerable attention by developmental psychologists (e.g., Flavell, 1979; Forrest-Pressley, MacKinnon, and Waller, 1985), interested in how children learn to manage the cognitive activities involved in reading, comprehending, memorizing, and paying attention. However, it is more informative for the present purposes to reference the expert/novice literature.

There is abundant evidence for the significance of metacognition in expert problem solving. While experts may be said to "recognize" familiar problems, recognition is sometimes achieved through the evaluation of intermediate results. For example, according to Larkin, et al. (1980), physics experts often construct and examine a sketch of the superficial objects and relations in a physics problem in order to determine the next step: If the depicted system is familiar, the expert may proceed directly to the equations required for solution. If the system is unfamiliar, the expert constructs an idealized representation (i.e., a free-body diagram), which is then used in the generation of solution equations. According to Chi, Glaser, and Rees (1982), this qualitative analysis of a problem is not a discrete phase that is concluded prior to the generation of quantitative equations. They found that experts returned to, and refined, the initial gross representation when necessary throughout the course of the problem. In short, experts manipulate the situation until they recognize it. That is, they change their representation of the problem until it makes contact with their knowledge. Metacognitive skill is required in judgments of familiarity and of how best to transform the problem to make it familiar.

Metacognition also plays a role after the problem has been recognized and (apparently) "solved." Physics experts utilize the abstract physical representation of a

problem to verify the correctness of their method and result, e.g., by checking whether all forces are balanced, whether all entities in the diagram are related to givens in the problem, etc. Similarly, in chess, Simon (1972) observed that some masters search the space of future moves and countermoves to verify that the moves they recognized as best are in fact in the subset of good moves. More recent research has found that differences in search skill (i.e., depth, breadth, and speed) are correlated with chess expertise (Charness, 1981; Holding and Reynolds, 1982). Key aspects of searching to verify recognized answers are metacognitive: the processes of initiating search, monitoring and evaluating its results, and deciding when it should be terminated.

In sum, metacognitive processes are crucial in two phases of intuitive decision making:

- Constructing of a situation model or plan when recognition is uncertain.
- Verifying the results of recognition

We have devised a model that incorporates both recognition and facilitative processes, and we call it the Recognition/Metacognition model (Cohen, 1993a). It has three key components (see figure #2): Quick Test, Critiquing, and Correcting. Each represents a different category of skill in situation understanding and decision making. We will address each in turn.

2.5 Metacognitive knowledge: The Quick Test

The Quick Test is a gate-keeping function that determines whether (1) to engage critiquing and correcting processes that might improve problem recognition or (2) whether the current level of recognition can (or must) suffice.

This process answers the question: Is there some reason to think more about my current model or plan, or should I act immediately? The answer is based on three more specific questions: (1) Do I have time before it is necessary to commit to a decision? (2) Are the stakes of an error high? and (3) Is there significant reason to doubt my initial situation assessment or plan? Quick Test skills thus involve sensitivity to the availability of time and potential costs of delay; sensitivity to the costs of errors that might occur if one does not delay, but invokes the best solution recognized to date; and sensitivity to the typicality of a situation and, conversely, to the presence of unusual or troubling features. If all three of the Quick Test conditions are satisfied, Quick Test inhibits the recognition-based response and triggers a process of knowledge-based reasoning. If at least one of the Quick Test conditions is not satisfied, the initial model or plan is accepted, and no critiquing or correcting takes place.

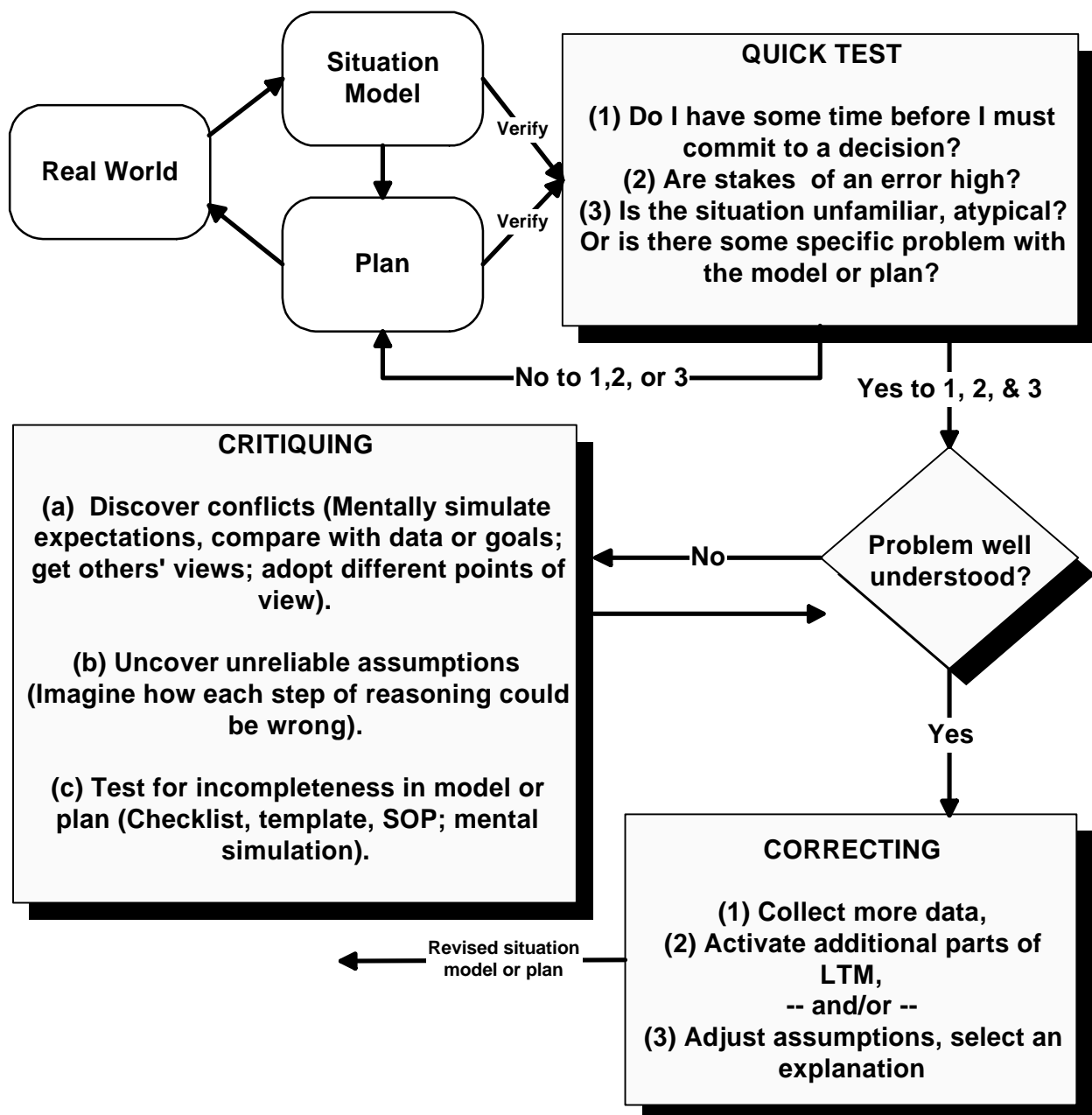


Figure 2: Metacognitive knowledge and process flow

The adaptive model integrates concepts from other models. According to Klein (1993), rapid recognition-primed decision making is expected under conditions of high time pressure. According to Connolly and Wagner (1988), rapid processing may occur when there is low cost of an error. According to both Klein and Rasmussen (1993), it is expected in highly familiar situations, that is from decision makers with situation-specific expertise. If any one of these conditions is true, then the answer to the corresponding Quick Test question is “no,” and correcting and critiquing do not take place.

The Quick Test can be a relatively explicit and conscious process, or a form of recognitional processing at a higher level that can be extremely rapid and virtually automatic.

2.6 Metacognitive knowledge: Critiquing

An initial situation model or plan may fail the Quick Test because specific problems are apparent or simply because the situation is complex or unfamiliar. In the latter case, the next goal in metacognitive processing is to answer the question: Are there specific potential problems with the current model or plan? Critiquing is the stage of ferreting out such problems.

Critiquing can result in the discovery of three kinds of problems in the current model or plan: incompleteness, unreliability, or conflict. Situation understanding or planning is incomplete if conclusions and options are not specific and detailed enough. Understanding and planning may be complete but unreliable if the link between data and evidence, or the link between actions and goals, is uncertain or conditional. Finally, even if understanding and planning are complete and free of obvious unreliable assumptions, there may be alternative, conflicting conclusions that better account for some of the data, or alternative actions that better achieve some of the goals.

Some critiquing methods are general-purpose. They are capable of uncovering problems of all three kinds. Mental simulation and retrieval of similar cases from experience are general-purpose in this sense. For example, by mentally simulating a course of action, an officer might be able to see if the current plan has any gaps, if it reliably achieves goals, and whether it conflicts with other goals. Similarly, comparison of a plan with an analogous previous experience might reveal gaps in the present plan, suggest places where the plan might not work reliably, or suggest alternative actions that have been adopted in the past. Other critiquing methods are more specialized in the kinds of problems they can uncover. For example, decision makers might use a checklist or standard operating procedure to ensure that all required components of a model or plan have been specified (completeness). They might adopt a devil's advocate technique in order to ferret out unreliable assumptions in an assessment or prediction. Data collection can determine if observations are consistent or conflicting with the current situation model or plan.

2.7 Metacognitive knowledge: Correcting

If no specific problem with the model or plan is identified by either quick verification or critiquing, then metacognitive processing in the current cycle is complete. But if a specific problem is found, the third major function of metacognition is enlisted: facilitating the construction of an improved model or plan. Whatever problem is discovered, three methods are available to solve it:

1. Collecting more data to fill gaps in the model or plan, confirm or disconfirm an assumption, or to resolve conflict
2. Activating existing knowledge in long-term memory, for the same purposes
3. Adding assumptions to fill gaps or resolve conflict, and dropping assumptions when they appear unreliable

Metacognitive processes play a role in choosing among these processes, and in regulating the process

that is chosen: (1) in selecting the amount and type of data collection, (2) in directing the search for knowledge in long-term memory, and (3) in adjudicating among competing possible assumptions.

Data collection. Sometimes there is time and opportunity to collect additional data to flesh out or resolve ambiguity in a model or plan, or confirm or disconfirm doubtful assumptions. The decision to collect more data rather than simply think about the problem involves metacognitive judgments regarding the amount of available time, the cost and potential risks of data collection, and the trustworthiness of information sources.

Knowledge activation. Metacognitive processes are crucial in guiding the serial activation of knowledge in long-term memory. Such searches are conceived of as controlled spreading activation. Executive processes determine which components of the current model will be attended, thus influencing the portions of long-term memory likely to be activated next (McClelland & Rumelhart, 1986). The values of the attended nodes are fixed, or clamped, at a high level of activation (in effect, accepting them provisionally or by assumption) in order to explore their implications. In the next cycle, new nodes may be clamped, and so on, until knowledge is activated that satisfies the goals of the search (or quick verification determines that time has run out). Different officers will attend to aspects of the situation in different orders. Some may focus attention on knowledge of terrain, others on knowledge of enemy strength, others on knowledge about enemy goals, and others on knowledge of enemy actions.

Metacognitive control may influence search in another way, by determining its temperature (Hinton & Sejnowski, 1986), i.e., by adjusting the degree of similarity required for a match between patterns in active memory and stored structures. At high temperatures, the activation net is cast wide, and far-fetched ideas have a significant chance of being considered. At low temperatures, an idea must have a very high degree of association with currently active beliefs to have a chance of being activated. High temperatures may be crucial, for example, when no plan is readily available that can achieve important goals.

Adjusting assumptions. If data collection is infeasible because of limitations in resources, time, or sources of information, and if definitive knowledge is not available or cannot be accessed from long-term memory, the situation assessor may revise his interpretation of the information. Metacognitive processes are crucial in the interpretative process of evaluating and revising assumptions. Decision makers think and act as if assumptions were true until there is some reason to doubt them. Conflict between

data and a situation model, or between two competing models, provides such a reason for doubt. Conflict indicates that at least one of the beliefs involved in building the models or interpreting the data was false. Conflict may thus trigger a metacognitive process of exposing and questioning assumptions. The process of revising beliefs to explain conflict requires a variety of metacognitive skills: awareness that conflict exists, an ability to uncover implicit assumptions that have created the conflict, sufficient awareness of the structure of one's beliefs to identify the assumptions that are central to a variety of models and plans, and recall of past episodes in which the same beliefs may have led to a conflict. Finally, the process of assumption revision calls for balancing the plausibility and the power of the resulting models and plans.

3. Teaching Critiquing Skills

3.1 Introduction

The simplest description of the training implications of the adaptive model involves contrasting them with the implications of the analytical and recognitional models.

If we view decision making as an analytical process, a perfectly appropriate stance in some circumstances, then it follows that instruction should focus on the transformations required to represent problems within the analytical model (for example, quantitative representations). Practice may be partitioned such that trainees study parts of the method before attempting to execute the whole. Examples should be varied in character to demonstrate the generality of the method, and they should be presented in a graduated sequence progressing from problems that clearly afford the analytical technique (that is, they require little in the way of transformation) to those that superficially seem inappropriate to the technique (that is, they are quite difficult to completely and accurately represent).

If decision making is taken to be a recognitional process, again a reasonable assumption in some situations, then the following inferences about training hold. Instruction should focus on goals, environmental conditions, and actions. In procedural terms, instruction should convey the following type of knowledge: if your goal is X amidst events Y, then perform action Z. Practice conditions should be realistic to promote accurate recognition and repetitive to facilitate automatic performance. Examples should be representative of the domain, though feedback may be manipulated to speed training.

Training that assumes an adaptive model of decision making should first of all convey the iterative nature of problem solving — from recognition to metacognitive checks, critiques, and corrections, back

to recognition. It must also aim to sensitize trainees to domain-specific cues concerning the time constraints, stakes, and familiarity of problems, as well as the nature of conflict, completeness and reliability in specific domains. It must convey methods of critiquing situation assessments and plans, and of making corrections that will enhance recognition. Practice should be designed to make metacognitive processes explicit. Such practice might involve reciprocal teaching (Palincsar and Brown, 1984), team exercises, explicit labeling of one's own activities, listening to experts label their thought processes, or critiquing the performance of peers. All of these methods help trainees make public otherwise hidden cognitive activities. Making principles explicit may help trainees transfer what they have learned to varied settings (Collins, Brown, & Newman, 1989). In addition, it may be appropriate to give trainees control over practice parameters that cue metacognitive activities; these include time, immediacy of feedback, quality of feedback, and difficulty. Exercises should employ non-routine cases, as these discourage simple recognitional solution and encourage the use of metacognitive skills.

We have attempted to bear these guidelines in mind in an ongoing study of the efficacy of training metacognitive skills. That training focuses on one metacognitive skill: critiquing situation assessments.

3.2 A course in critiquing skills

In teaching critiquing, we attempt to unify the three potential weaknesses of assessments (incompleteness, unreliability, and conflicting evidence) under a single concept: the plausibility of the assessment.

The analytical approach to plausibility is numerical assessment. The meaning of a piece of information for a particular hypothesis is summarized in a single number (e.g., a probability or a belief function) measuring its diagnostic impact. The result is an average that suffers two failings. The first is that quantitative solutions (e.g., such as hostile intent = .3; probability not hostile intent = .7) are inherently abstract, and thus difficult to comprehend. The second is that the coherence of the evidence underlying the average cannot be communicated in a natural, conversational manner (a requisite condition of good performance in a team setting), but only by reconstructing the complex analytical process.

In simple recognitional approaches, plausibility is represented by the degree of match or mismatch between a complete situation and a pre-stored template. The result is typically a single best-matching template. However, novel situations are liable to produce gross mismatches. Since recognitional processes are not, presumably, available for direct verbal report or analysis, the extent and cause of these mismatches

cannot be explained, nor can alternative matches be made explicit.

In the adaptive framework the end result is a single coherent situation model (an elaborated schema for a given situation). This distinguishes the adaptive framework from the analytical approach but is quite similar to the product of recognitional processing. However, the process of constructing the schema is explicit in the adaptive approach, unlike the recognitional process. Thus, the process is available for presentation and public scrutiny in a natural, conversational context. In particular, the situation assessor is able to articulate the assumptions underlying his or her assessment.

Metacognitive strategies for critiquing involve distinguishing between the normal interpretation of a cue and possible exceptions (see Toulmin, 1978). The initial recognitional response to a cue provides its normal meaning. For example, the absence of enemy artillery within shelling range may indicate that an encampment site is safe from shelling. Exceptions to this normal meaning can be generated by a method discussed in the next section when time is available, stakes are high, and the situation is unfamiliar. Perhaps the enemy is prepared to move artillery quickly within range, our scouts did not find an existing artillery site, or the enemy plans to use air assault. These exceptions constitute assumptions that must be false if the assessment of a safe encampment is true. However, the decision maker may never actually have recognized and discarded these assumptions in formulating the assessment. Metacognitive skills training may help officers uncover hidden assumptions early.

The same skills used to critique situation assessments can be extended to analyzing plans. Thus, critiquing skills can help an officer identify hidden assumptions in plans, and deal with them in a variety of ways. The decision maker may decide that an assumption is plausible on the basis of recalled evidence, confirm its truth by examining extant data or requesting intel, take steps to make the assumption true through proactive strategies, adopt a contingency plan in case the assumption is false, develop a model or plan that does not depend on the assumption at all, or accept the assumption as a known risk.

In an ongoing study we provide training in two metacognitive skills. The first method is designed to help officers critique assessments or plans to find hidden assumptions before they cause problems. In essence, the method helps counteract overconfidence. The second method is designed to help officers refine or change their assessments after hidden assumptions, inadequate plans, or other causes produce problems. It is a cure for underconfidence, or confusion.

3.3 Finding Hidden Assumptions

The method of finding hidden assumptions consists of four steps.

1. Select a critical part of your assessment — even if you are confident of it.
2. Imagine that a “perfect” intelligence source (such as a crystal ball) tells you that this part of your assessment is wrong.
3. Explain how it could be wrong
4. The “perfect” intelligence source now tells you that this explanation is wrong...go back to step 3.

The product of this exercise is a list of negations of assumptions that underlie the assessment. For the assessment to stand, the officer must demonstrate that the assumptions are unreasonable, that is, they cannot plausibly be used to generate an opposing assessment. The following illustration — drawn from an interactive classroom exercise at Ft. Lewis — may clarify this point.

Suppose that an officer’s assessment includes the claim that the enemy will cross the river at location X. He bases this claim on arguments concerning the distance the enemy must travel to his supposed objective, the shallow depth of the river, and concealment opportunities along the bank. The officer is confident of this assessment; however stakes are high and there is time to critique the assessment, so he does so. Following the method, above, he imagines that a “perfect” intelligence source tells him that the enemy will not cross at location X, and demands that he explain this failure in his interpretation of the evidence. He cycles through steps three and four to generate the following list of assumptions:

- “The enemy anticipates that our force will be at location X.”
- “The enemy will detect the movement of our force to location X.”
- “There are good crossing sites that we missed.”
- “The enemy doesn’t know how good a location X is.”
- “The enemy doesn’t have any river crossing assets. He can’t cross the river at all.”
- “The enemy’s river crossing assets are so good that he can cross elsewhere.”
- “The enemy has a large enough force that he can accept casualties crossing elsewhere.”
- “The enemy’s objectives are different. He doesn’t need to cross at all.”
- “The enemy will use air assault to get across the river, rather than cross it.”

These nine ideas are exceptions to the officer’s recognitional assessment of the situation. To maintain the assessment that the enemy will cross at location X, the officer must prove to himself that it is reasonable to assume they are false or that he has some way to handle the situation if they are true.

Table #1 includes several of the types of responses that were discussed above: testing the truth of an assumption through recall of evidence or data collection, adopting proactive strategies, adopting contingency plans, and accepting the assumption as a known risk.

We have found this method to be fast (usually less than five minutes in duration) and highly productive. It is particularly effective for officers when they are confident of their assessments. It raises issues that force officers to earn their own confidence by strengthening their assessments and plans to compensate for potential weaknesses.

Assessment: The enemy will cross at X.	
Exceptions	Responses
“The enemy anticipates that our force will be at location X.”	Place our forces elsewhere then move.
“The enemy will detect the movement of our force to location X.”	Use deception.
“There are good crossing sites that we missed.”	Consult with a specialist in river crossings or scout enemy movements towards other crossing sites.
“The enemy doesn’t know how good a location X is.”	Dismiss this as implausible given recent intel on enemy surveying and scouting activity.
“The enemy doesn’t have any river crossing assets. He can’t cross the river at all.”	Dismiss this. It presents no problem.
“The enemy’s river crossing assets are so good that he can cross elsewhere.”	Collect intel to verify or disprove.
“The enemy has a large enough force that he can accept casualties crossing elsewhere.”	Dismiss this as implausible given current, reliable intel.
“The enemy’s objectives are different. He doesn’t need to cross at all.”	Adopt a contingency plan.
“The enemy will use air assault to get across the river, rather than cross it.”	Accept this risk.

Table 1: Example of exceptions to the interpretation of evidence, and methods of handling the exceptions.

3.4 Handling the Unexpected

Despite expert assessment, careful planning, and thorough critiquing, officers often are confronted by unexpected events. The second method in which we have trained officers is designed to help them handle the unexpected, either by explaining events in terms of their current assessment, or, if explanations are implausible, by altering their assessments to conform to the new state of the world. The procedure consists of these steps:

1. Notice an unexpected event.
2. Try to explain the event in terms of your current assessment.
3. Evaluate the plausibility of your explanations for all unexpected events to date.
4. If the explanations are not plausible, change your assessment

Several caveats and tips pertain to this method. First, it is sometimes enough simply to notice an unexpected event. This is the case if there is no time to analyze the event, if the event does not raise the stakes of the situation above some threshold, or if the event does not lower familiarity with the situation.

Second, the officer can use two tools to generate explanations. The “perfect” information source is

productive. It instructs the officer to imagine that the assessment is true, and that he must explain the surprising event. Trainees often find it useful to focus the technique by specifying as the domain of explanations the categories of METT-T (mission, enemy, troops, terrain and weather, and time available). For example, the trainee may consider how an event might be explained in terms of actions of his own troops, the terrain or weather, enemy tactics, enemy equipment, and so forth. As discussed above, the product of these methods is an assumption that must be verified, planned against, or handled in some other way.

Third, the coherence of the assessment is a function of the most plausible union of explanations generated to account for unexpected events. An example may clarify this point. It is presented here in a table format used during training (see table #2). The table shows an assessment and three events that are surprising in light of the assessment. The decision maker has used the perfect intelligence source to generate a set of explanations for each event. The METT-T category used to generate each explanation is presented in brackets. Explanations marked with an asterisk are those the officer considers the most plausible of the

ones he generates using the “perfect” intelligence source.

Note that the best overall account for a series of unexpected events may balance simplicity and plausibility. For example, taken separately, the most plausible three explanations for the events in the example concern troops, enemy deception, and enemy tactics. However, it may be improbable to an officer

that all three of these explanations are independently true. Thus, for example, he may choose a somewhat simpler account, in which a single cause — our own aggressive interdiction campaign — accounts for the destruction of bridges and radio silence, and a second assumption concerning enemy tactics explains reinforcements in the north.

Assessment: The enemy plans a diversionary attack in the north, and a main attack in the south.	
Events	Explanations
Southern enemy force has destroyed a major bridge to his front	<p>*[Troops] Perhaps it was our own forces, not the enemy, that destroyed the bridge.</p> <p>[Enemy (deception)] Perhaps the destruction is a deception to make you think the main attack will not be in the southern sector.</p> <p>[Enemy (mistake)] Perhaps the destruction of the bridge was a mistake by the enemy.</p>
Enemy has initiated radio silence in the north and the south.	<p>[Troops] The enemy is not responsible for radio silence. Our interdiction campaign may have destroyed critical enemy radio facilities.</p> <p>*[Enemy (deception)] The enemy is concealing the location of the attack by instituting radio silence everywhere.</p> <p>[Enemy (equipment)] The enemy’s C2 equipment has failed.</p>
Reinforcements have arrived in the north.	<p>[Enemy (deception)] The enemy is “showing” arrival in the north before shifting forces stealthily to the south.</p> <p>*[Enemy (tactics)] The enemy may be putting green forces on line in the north to execute a secondary attack.</p> <p>[Enemy (mistake)] The northern movement of reinforcements may be a mistake.</p>

Table 2: Table format used to train both and finding hidden assumptions and handling the unexpected.

An officer may eventually find that he cannot construct a coherent account of all of the unexpected events. There may be just one too many events to explain. Suppose that the example above were extended to include the surprising movement of two enemy motorized rifle regiments from the south to the north. Then it might be the case that no additional explanation (such as enemy deception or errors) could make tenable the assessment that the enemy plans a main attack in the south and a diversionary attack in the north. In that case, a new assessment is in order, per the fourth step of the procedure outlined above.

We teach the process of generating and justifying a new assessment using the same type of table employed above. The process begins by examining the unexpected events to date (ignoring explanations of their meaning) and arriving at an assessment of them. This process can be recognitional. To tap this potential, the trainee is instructed to answer the question, “What do these events usually mean?” In the case above, that interpretation might be that the enemy

plans its main attack in the north. A new table similar to table #2 is then constructed, and the events column is filled with evidence that supported the original assessment (now discarded). Standard interpretations of these events would probably contradict the new assessment. Thus, these events must be explained in a manner that is consistent with the new assessment. The list of unexpected events and their explanations grows as surprises arise, until the assessment is again replaced or the situation is resolved.

3.5 Status Report on a Pilot Study

We have taught these techniques to 33 officers, thus far. Trainees perform a pretest, receive the training, and take a posttest. The pretest and posttest materials are counterbalanced to control for possible differences in the difficulty of materials. A control group receives a pretest, discusses military tactics, and completes a posttest. This aspect of the design controls for the effect of practice during training.

Training for the experimental group consists of reading a short illustrated manual, summary lectures by the instructor, and interactive exercises in which officers critique situations from their own experience, and assessments they have made.

The test materials consist of a military scenario and a dozen problem statements. The scenario describes the invasion of an island nation by its neighbor and the first actions taken by the U.S. in response. It consists of a chronologically organized status report, a mission statement, and a map of the island. The problem statements consist of two parts, each printed on a separate page. The first part contains background information (150 words, on average) concerning a particular topic (e.g., the status of hostages held by enemy forces, the air defense equipment and readiness of the enemy) and an assessment of the situation regarding that particular topic. The second part consists of identical text plus new information concerning the topic (not a new assessment).

On each part of each problem, subjects are asked to perform two tasks, phrased as follows:

- Please evaluate the assessment. In what ways is the reasoning good? bad?
- Do you agree with the assessment? Use this scale:
 1. Strongly disagree
 2. Moderately disagree
 3. Don't know
 4. Moderately agree
 5. Strongly agree

Six of the twelve problems appear on the pretest and six on the posttest. Answer sheets consist of one piece of blank paper per problem, labeled with the problem number.

The study and preliminary analysis of its results are in progress. Thus, far, we can report that corps planners and other officers at the level of Captain, Major, and Lt. Colonel find the training useful, and ask that the presentation be lengthened from the current two hours to a day or more. Subjective assessments aside, we use as dependent measures the quantity and quality of issues that trainees raise in their evaluations of the printed assessments. Quality is assessed by expert judges blind to the test conditions. However, we are not satisfied that this approach will net strong results. It is a significant challenge to effect and detect differences in the use of briefly trained skills on complex cognitive tasks.

4. Conclusion

We have explored only part of the potential curriculum in metacognitive skills, and we have used only a few of the potential training techniques to do so. Here we wish to raise some of the questions that pertain to future research.

Skills relevant to assessing the time and stakes of a situation (part of what we call the Quick Test) may require training that hones recognitional processing of the tempo and dangers of specific scenarios. We are interested in investigating how recognitional training can be structured to help officers generalize the lessons learned from instruction that is so specific in content. The issue of generalization also arises in considering how to train the third component of the Quick Test: metacognitive sensitivity to the familiarity of situations.

Many of the skills needed to correct assessments and plans may already be well taught by the Army. We are thinking here of such skills as developing contingency plans. However, it would be useful to study how to help officers link the outcomes of metacognitive critiquing processes to their current skills, and to investigate which correction skills are not yet addressed in the Army curriculum.

At a more general level, we are concerned with the manner in which the metacognitive skills used by individuals interact with the social processes employed by groups of officers who formulate and critique assessments.

The representation of knowledge is a significant issue at the levels of the individual and the group. For example, we are concerned with how schemas and situation models can best be represented for individual use in training and in the field. It is also unclear whether the representations that best facilitate the thinking of individuals will optimally support group interactions.

These and other issues remain to be systematically addressed in naturalistic settings. It is our hope that studies of training interventions may help Army instructors devise courses in metacognitive skills, courses that are accurate in content and principled in method.

Finally, we believe that the Recognition/Metacognition model also has implications for the design of decision support systems and man-machine interactions in the Army environment. We have begun to assess its potential in these areas.

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